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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P211924PCT	**FOR FURTHER ACTION** See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/NL 03/00924	International filing date *(day/month/year)* 23.12.2003	Priority date *(day/month/year)*
International Patent Classification (IPC) or both national classification and IPC H03M13/29, H04L1/00		
Applicant TELEFONAKTIEBOLAGET LM ERICSSON et al		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 8 sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the opinion
   II ☐ Priority
   III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☐ Lack of unity of invention
   V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   VI ☐ Certain documents cited
   VII ☐ Certain defects in the international application
   VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
21.07.2005	01.03.2006
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Burkert, F Telephone No. +49 89 2399-6975

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, Pages

5-8	as originally filed
1-4	received on 01.12.2005 with letter of 25.11.2005

Claims, Numbers

1-9	filed with telefax on 10.02.2006

Drawings, Sheets

1/1	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:
   - ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-9
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-9
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-9
	No:	Claims	

2. Citations and explanations

   see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Reference is made to the following documents:

   D1: US-B2-6 574 291 (DOETSCH MARKUS ET AL) 3 June 2003 (2003-06-03)
   D2: GB-A-2 360 425 (SIEMENS AG) 19 September 2001 (2001-09-19)
   D3: VALENTI M C ET AL: "Iterative channel estimation and decoding of pilot symbol assisted turbo codes over flat-fading channels", in IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, SEPT. 2001, vol. 19, no. 9, pages 1697-1705, XP002285321

2. The subject-matter of independent claims 1 and 5 relates to a method and a device, respectively, for decoding of a convolutionally encoded input signal, wherein said input signal is scaled by a scaling factor, which is updated for a next iteration on the basis of a combination of a posteriori likelihood data based on the turbo decoder output and a priori likelihood data based on that part of the scaled input signal that is associated with the systematic part, wherein an estimate of the mean value of the signal amplitude and an estimate of a noise variance is used. The estimate of the mean value of the signal amplitude is derived based on the log-likelihood ratio from the most recent turbo decoder iteration and the estimate of the noise variance is calculated using normalized systematic bits and a bias correction value that depends on the log-likelihood ratio from the most recent turbo decoder iteration.

3. The closest available prior art is represented by Documents D1 and D2.

(a) Document D1 discloses a method for turbo decoding in which the input data is scaled by means of a scaling factor, which relates to the channel state information. Said scaling factor is updated for the next decoding iteration on the basis of the re-encoded turbo decoder output and the input signal.

(b) Document D2 discloses a turbo decoder, which contains a circuit for updating parameters for weighting the input signal, wherein said parameters are updated on the basis of the weighted input signal and the re-encoded turbo decoder output.

(c) The decoding method and the decoder according to independent claims 1 and 5, respectively, differ therefore from the disclosures of Documents D1 and D2 in that the scaling factor is updated in dependence on a combination of a posteriori likelihood data based on the turbo decoder output and a priori likelihood data based on that part of the scaled input signal that is associated with the systematic part, whereas in Documents D1 and D2 the scaling or weighting factor is updated in dependence on the re-encoded turbo decoder output. That is, the turbo decoder output is not used for the update of the scaling factor. Furthermore, Documents D1 and D2 do not use a mean value of the of the signal amplitude and an estimate of the noise variance as defined in independent claims 1 and 5 for updating the scaling factor.

(d) Therefore, the subject-matter of claims 1 and 5 is new in the sense of Article 33(2) PCT.

(e) In the context of iterative turbo decoding, the refinement of parameters related to the channel state between iterations is widely applied (cf. e.g. Documents D1, D2 and D3). In Document D3 estimates of fading amplitudes and noise variance are iteratively refined using turbo decoder log-likelihood ratios.

(e1) However, none of the available citations discloses or suggests to update any of these parameters in dependence on a combination of a posteriori likelihood data based on the turbo decoder output and a priori likelihood data based on the scaled input signal being subject to decoding using a mean value of the signal amplitude and an estimate of the noise variance as defined in independent claims 1 and 5.

(f) As a consequence, the person skilled in art would not find any indications or prompts in the available prior art to modify the methods and the decoders of Documents D1 and D2 as set out in independent claims 1 and 5.

(g) Therefore, the subject-matter of independent claims 1 and 5 is considered to involve an inventive step (Article.33(3) PCT).

4. Independent claim 9 defines a computer program product that provides a processing system with the capability to execute a method according to claim 1.

(a) Therefore, the subject-matter of claim 9 is novel and inventive for the same reasons as set out above with regard to claim 1.

5. Claims 2-4 and 6-8 are dependent on claims 1 and 5, respectively, and as such also meet the requirements of the PCT with respect to novelty and inventive step (Article 33 PCT).

Further Remarks:

1. The application does not meet the requirements of Article 6 PCT for the following reason:

(a) Claims 7 and 8 are directed to decoder devices and have been phrased as claims dependent on "one of the preceding claims".

(b) However, only claims 5 and 6 are directed to a decoder device and claims 1-4 are directed to methods for decoding.

(c) This renders the definition of the subject-matter of claims 7 and 8 unclear for the dependencies of said claims on claims 1-4.

Method and device for decoding convolutionally coded data

Field of the invention

The present invention relates to a method for decoding a convolutionally coded input data signal y comprising multiplying the input data signal with a scaling factor L_c, demultiplexing the multiplied input data signal $L_c y$ into three signals which are related to systematic bits and parity bits, a demultiplexed input data signal $L_c S$ being associated with the systematic bits, e.g. in parity signals and a systematic signal, and turbo decoding the demultiplexed input data signal $L_c S$ in order to obtain turbo decoded output data Λ. In a further aspect, the present invention relates to a decoder device as defined in the preamble of claim 5.

Prior art

Such a method of decoding data and a decoder device are known from American patent US-B-6,574,291, which discloses a turbo-code decoder with iterative channel parameter estimation.

American patent publication US-B-6,393,076 describes a method for decoding turbo codes using data scaling. Convolutionally coded input data is decoded in a near ideal manner. A portion of the input data is buffered, after which a mean of the data in the portion of the input data is calculated. Then, a root-mean-square value of the portion is calculated using the mean. A scaling factor is derived from the root-mean-square value, which scaling factor is used to scale the portion of the input data before the turbo decoding step.

These disclosed methods have the disadvantage that the scaling factor computation is not based on a-posteriori likelihood information, which leads to additional loss. Especially in mobile applications using these kind of coding, every additional loss has a negative effect on system performance.

The publication of El-Gamal, H., High capacity Synchronous FH/SSMA networks with turbo coding, IEEE Intern. Symp. on Spread Spectrum Techniques, 1998, p973-977, provides a similar method for scaling the input data. The method consists of computing the noise variation, which is subsequently applied to form log-likelihood values. This method has the disadvantage that it assumes the signal

amplitude as normalized to unity. This is a simplification not valid for practical receiving equipment, and therefore negatively impacts the system performance.

The article by M.C. Valenti et al. 'Iterative channel estimation and decoding of pilot symbol assisted turbo codes over flat-fading channels', IEEE Journal on selected areas in communications, Sept. 2001, IEEE, USA, vol. 19, no.9 pages 1697-1705 discloses a method for coherently detecting and decoding turbo-coded binary shift keying signals transmitted over frequency flat fading channels. The use of hard-decision feedback and soft-decision feedback are considered.

The British patent application GB-A-2 360 425 discloses a channel state information estimation for turbo-code decoders. In this document, only the use of a maximum a posteriori (MAP) probability decoding algorithm is disclosed.

Summary of the invention

The present invention seeks to provide an improved decoding scheme for use in transceivers using a maximum-a-posteriori (MAP) decoder, or related techniques such as Logarithmic MAP (LOGMAP).

According to the present invention, a method according to the preamble defined above is provided, having the features of the characterising part of claim 1. By combining these a posteriori and a priori likelihood data, it is possible to improve the performance of the decoding method without the need of much additional hardware or software resources.

In an embodiment of the present invention the scaling factor is updated according to

$\hat{L}_c = \frac{2}{\hat{c} \cdot \hat{\sigma}_{n'}^2} \cdot L_c$, in which $\hat{L}_c$ is the updated scaling factor.

This makes the present method accurate and fast, so that it secures the advantage (simulations show the loss compared to the theoretical optimum is about 0.03dB), and is applicable in fast fading or time-variant channels. It has been shown that about 0.1 to 0.2dB in sensitivity improvement for turbo codes can be achieved, compared to prior art methods.

In a further embodiment, the scaling factor L_c is initialized either as a fixed value, as the result of an initial number of iterations using a known algorithm, as the result of filtering over subsequent iterations and coding blocks, or as the result of

SNR/SIR estimation of the input data signal. Initialization can thus be accomplished using very simple solutions or more complex but well known solutions.

In an even further embodiment of the present invention, the method further comprises calculating the variation of the scaling factor in subsequent iterations and, when the variation after a predetermined number of iterations is above a predetermined threshold value, reverting to a different scaling factor calculation method and/or turbo decoding method. The different scaling factor calculation method may e.g. be a fixed scaling factor, a Log-MAX method or a SOVA method (Soft Output Viterbi Algorithm). In this manner, a simple divergence monitoring of the iterative method can be accomplished, using known algorithms as back-up.

In a further aspect of the present invention, a decoder device is provided according to claim 5. Further embodiments of the present decoder device are described in the dependent claims. Accordingly, the present decoder device provides an improved performance over prior art devices. Because the sensitivity improvement only requires a small hardware cost, the sensitivity improvement is a pure bonus. The important system aspects, which influence sensitivity, are signal strength, i.e. range/coverage/battery life, noise figure, and interference, i.e., air interface capacity. Hence, the advantage of the present invention can be translated into a coverage increase (<1% more range), increased mobile battery life time (2 to 4% less transmit power), relaxed noise figure requirements (0.2dB less), or improved capacity users on the air interface (2 to 4% more). This yields a larger cell-coverage and lower power usage for the mobile, which in turn gives less interference, and therefore more capacity.

In an even further aspect, the present invention provides a computer program product, which comprises computer executable code, which when loaded on a processing system, provides the processing system with the capability to execute the present method. The processing system may comprise a microprocessor and peripheral equipment, a digital signal processor or a combination of both to execute the present method.

Short description of drawings

The present invention will be discussed in more detail below, using a number of exemplary embodiments, with reference to the attached drawings, in which

amended page 4

Fig. 1 shows a block diagram of an embodiment of the decoding scheme according to the present invention.

Detailed description of exemplary embodiments

The present application may be advantageously applied in decoding of systematic forward error-correcting codes, such as the parallel concatenated convolutional turbo codes found in third generation mobile telecommunication systems (3GPP). The present invention can be employed in transceivers using a maximum-a-posteriori (MAP) decoder, or related techniques, such as Log-MAP.

Iterative MAP and Log-MAP decoding are asympotically optimum. Sub-optimal decoding algorithms, such as soft output Viterbi algorithm (SOVA) or approximated LOGMAP (Log-Max), are simpler implementation-wise, yet about 0.5dB short of the MAP and Log-MAP performance.

The problem with achieving the full extent of MAP performance is the requirement that the input data is defined as a (log) likelihood ratio. With the present

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CLAIMS (Amended 10.02.2006)

1. Method for decoding a convolutionally coded input data signal y comprising

- multiplying the input data signal with a scaling factor L_c;
- demultiplexing the multiplied input data signal $L_c y$ into three signals which are related to systematic bits and parity bits, a demultiplexed input data signal $L_c S$ being associated with the systematic bits;
- turbo decoding the demultiplexed input data signal $L_c S$ in order to obtain turbo decoded output data Λ,

characterized in that, the scaling factor L_c is updated for a next iteration in dependence on a combination of a posteriori likelihood data based on turbo decoded output data Λ and a priori likelihood data based on the demultiplexed signal $L_c S$, using an estimate of the mean value of the signal amplitude $\hat{c}$ and an estimate of the noise variation $\hat{\sigma}^2_{n'}$,

in which the estimate of the mean value of the signal amplitude is equal to

$$\hat{c} = \frac{1}{N}\sum_{i=0}^{N-1}\operatorname{sgn}(\Lambda_i)\cdot L_c \cdot s_i,$$

where N is the number of bits in a coding block of the input data signal, s_i is the i^{th} systematic bit, $\hat{c}$ is the estimation of the mean value of the amplitude of the scaled systematic bits $L_c \cdot s_i$ and Λ_i is the log-likelihood ratio resulting from the most recent turbo decoder iteration,

and in which the noise variance estimation $\hat{\sigma}^2_{n'}$ equals

$$\hat{\sigma}^2_{n'} = \frac{1}{N-1}\sum_{i=0}^{N-1}(s'_i-1)^2\cdot P_i(1)+(s'_i+1)^2\cdot P_i(0)-K;$$

the probability of the i^{th} bit being zero is estimated like $\Pr\{x_i=0\}=P_i(0)=\frac{1}{1+e^{-\Lambda_i}}$

and the probability of that bit being one like $\Pr\{x_i=1\}=P_i(1)=\frac{1}{1+e^{\Lambda_i}}=1-P_i(0)$;

the normalised systematic bits s'_i are calculated as $s'_i=\frac{L_c\cdot s_i}{\hat{c}}$;

and where K is a bias correction computed as $K = \frac{1}{N}\sum_{l=0}^{N-1} 2\cdot(P_l(0) - P_l(1))\cdot s_l' - 2$.

2. Method according to claim 1, in which the scaling factor is updated according to $\hat{L}_c = \frac{2}{\hat{c}\cdot\hat{\sigma}_{n'}^2}\cdot L_c$, in which $\hat{L}_c$ is the updated scaling factor.

3. Method according to one of the preceding claims, in which the scaling factor L_c is initialized either as a fixed value, as the result of an initial number of iterations using a known algorithm, as the result of filtering over subsequent iterations and coding blocks, or as the result of SNR/SIR estimation of the input data signal y.

4. Method according to one of the preceding claims, further comprising calculating the variation of the scaling factor in subsequent iterations and, when the variation after a predetermined number of iterations is above a predetermined threshold value, reverting to a different scaling factor calculation method and/or turbo decoding method.

5. Decoder device for decoding a convolutionally coded input data signal y comprising

- a multiplication element (8) for multiplying a received input data signal y with a scaling factor L_c;
- a demultiplexer (6) for demultiplexing the multiplied input data signal $L_c y$ into three signals which are related to systematic bits and parity bits, a demultiplexed input data signal $L_c S$ being associated with the systematic bits;
- a turbo decoder (5) for decoding the demultiplexed input data signal in order to obtain turbo decoded output data Λ,

characterized in that, the decoder device (10) further comprises an adaptive scaling element (7) which is arranged to update the scaling factor L_c for a next iteration based on a combination of a posteriori likelihood data based on turbo decoded output data Λ and a priori likelihood data based on the demultiplexed signal $L_c S$, using an

estimate of the mean value of the signal amplitude $\hat{c}$ and an estimate of the noise variation $\hat{\sigma}^2_{n'}$,

in which the estimate of the mean value of the signal amplitude is equal to

$$\hat{c} = \frac{1}{N}\sum_{i=0}^{N-1} \operatorname{sgn}(\Lambda_i)\cdot L_c \cdot s_i\,,$$

where N is the number of bits in a coding block of the input data signal, s_i is the i^{th} systematic bit, $\hat{c}$ is the estimation of the mean value of the amplitude of the scaled systematic bits $L_c \cdot s_i$ and Λ_i is the log-likelihood ratio resulting from the most recent turbo decoder iteration,

and in which the noise variance estimation $\hat{\sigma}^2_{n'}$ equals

$$\hat{\sigma}^2_{n'} = \frac{1}{N-1}\sum_{i=0}^{N-1}(s'_i-1)^2\cdot P_i(1) + (s'_i+1)^2\cdot P_i(0) - K\,;$$

the probability of the i^{th} bit being zero is estimated like $\Pr\{x_i = 0\} = P_i(0) = \frac{1}{1+e^{-\Lambda_i}}$

and the probability of that bit being one like $\Pr\{x_i = 1\} = P_i(1) = \frac{1}{1+e^{\Lambda_i}} = 1 - P_i(0)$;

the normalised systematic bits s'_i are calculated as $s'_i = \frac{L_c \cdot s_i}{\hat{c}}$;

and where K is a bias correction computed as $K = \frac{1}{N}\sum_{i=0}^{N-1} 2\cdot\left(P_i(0) - P_i(1)\right)\cdot s'_i - 2$.

6. Decoder device according to claim 5, in which the adaptive scaling element (7) is further arranged to update the scaling factor according to $\hat{L}_c = \frac{2}{\hat{c}\cdot\hat{\sigma}^2_{n'}}\cdot L_c$, in which $\hat{L}_c$ is the updated scaling factor.

7. Decoder device according to one of the preceding claims, in which the decoder device is further arranged to initialize the scaling factor L_c either as a fixed value, as the result of an initial number of iterations using a known algorithm, as the result of filtering over subsequent iterations and coding blocks, or as the result of SNR/SJR estimation of the input data signal y.

8. Decoder device according to one of the preceding claims, in which the decoder device is further arranged to calculate the variation of the scaling factor in subsequent iterations and, when the variation after a predetermined number of iterations is above a predetermined threshold value, reverting to a different scaling factor calculation method and/or turbo decoding method.

9. Computer program product, which comprises computer executable code, which when loaded on a processing system, provides the processing system with the capability to execute the method according to one of the claims 1 through 4.